Canada. National energy
board
Staff paper
NEB - SS22

National Energy Board

ENERGY SUPPLY AND DEMAND

(Aggregation of Statistics Dealing with Energy Obtained from Different Sources and in Various Forms)

Staff Paper

OTTAWA, CANADA
SEPTEMBER, 1969

NEB - SS22

National Energy Board

ENERGY SUPPLY AND DEMAND

(Aggregation of Statistics Dealing with Energy Obtained from Different Sources and in Various Forms)

Staff Paper

Ottawa, Canada
September, 1969

NEB-SS22

Available by mail from the Queen's Printer, Ottawa,
and at the following Canadian Government bookshops:

HALIFAX
1735 Barrington Street

MONTREAL
Æterna-Vie Building, 1182 St. Catherine St. West

OTTAWA
Daly Building, Corner Mackenzie and Rideau

TORONTO
221 Yonge Street

WINNIPEG
Mall Center Bldg., 499 Portage Avenue

VANCOUVER
657 Granville Street

or through your bookseller

Price : 75 cents Catalogue No. NE12–2/22

Price subject to change without notice

The Queen's Printer for Canada
Ottawa, 1969

ENERGY SUPPLY AND DEMAND

(Aggregation of Statistics Dealing with Energy Obtained from Different Sources and in Various Forms)

In attempting to compile overall energy supply and demand statistics on the basis of a common denominator, e.g. in terms of British Thermal Units (Btu's), difficulties are often encountered in determining the true measure of the energy derived from a variety of sources. The differences in form and quality and also the great variations in the efficiencies with which these diverse forms of energy can be utilized in different end-uses give rise to considerable problems.

Significant variations in accounting for energy supply and demand can occur, according to the interpretations and treatment of available data. Overall trends in the use of energy can be interpreted differently and the definition of the contribution which specific forms of energy make to total production or consumption of energy can also show corresponding variations. Clarification of the issues involved in the proper accounting for energy in the economy consequently constituted an integral part of the Board's research in relation to its energy supply and demand forecasts. A brief discussion of the relevant issues was considered of possible value generally to those engaged in market research and forecast studies and, in consequence, it was thought

helpful to make the relevant notes on this subject available to those interested in the subject matter.

For purposes of illustration, statistics for the year 1965 are used in the attached diagram, which displays the basic thinking behind this discussion.

In the case of fossil fuels, i.e. petroleum, natural gas, as well as coke and coal, energy is produced by a chemical process of combustion in the form of heat. The following tabulation provides a guide to the factors generally used in Canada when expressing the energy normally produced by combustion of these fuels in terms of Btu's:

TABLE 1

	Btu's per Barrel
Petroleum Fuels	
Liquid Propane	3,843,000
Liquid Butane	4,309,200
Aviation Gasoline	5,048,400
Aviation Turbo Fuel	5,414,500
Motor Gasoline	5,216,400
Kerosene	5,670,000
Distillates:	
No. 1	5,712,000
No. 2	5,817,000
No. 3	5,951,400
No. 4	6,090,000
Average (weighted)	5,825,400
Residual Fuel Oil:	
No. 5	6,237,000
No. 6	6,384,000
Average (weighted)	6,287,400
Crude Petroleum (weighted average)	5,800,200

TABLE 1 - cont'd.

Coal and Coke	Btu's per Short Ton
American Anthracite	25,400,000
Bituminous Coal:	
a) High Volatile	25,800,000
b) Medium Volatile	26,000,000
c) Low Volatile	27,600,000
Average	26,200,000
Sub-bituminous Coal	19,000,000
Lignite	14,000,000
Briquettes	28,000,000
Coke (average)	24,800,000
Wood - well-seasoned	**Btu's per Short Ton**
Hard Maple (air dried - 18%)	14,000,000
Soft Pine Slabs (air dried - 18%)	14,800,000
Natural Gas	**Btu's per Cubic Foot**
@ 60^{o}F and 14.73 psia (nominal)	1,000*

* The Btu content of pipe line quality natural gas varies according to source of supplies and the treatment of the raw gas.

(The treatment of electricity, i.e. hydro, thermal and nuclear, is discussed later on in this paper.)

It is generally recognized that a considerable proportion of energy from fossil or nuclear fuels is lost in the process of converting the heat generated by these fuels into energy that is to be employed for doing mechanical work. It seems accepted that on average only about one-third or less of the original energy "input" can be used in the form of effective work or energy

"output", whether the energy in the form of heat is used to run a steam turbine, an internal combustion engine or some other similar mechanism. In order to account for the "demand on energy resources" on the one hand and for the "effective energy" used on the other, the attached schematic diagram has been drawn up.

The diagram first of all shows the flow of energy derived from fossil and nuclear fuels (i.e. heat) either to

a) electricity generation (i.e. production of secondary energy) or to

b) uses other than electricity generation.

Taking the "other uses" of energy derived from fossil fuels first, it is evident that this energy can be used either for

a) producing heat (e.g. space or industrial process heat) or for

b) mechanical work (e.g. in internal combustion engines).

The apportioning of energy between effective end-use (block H on the diagram) and losses and waste (block F on the diagram) constitutes a major problem, since efficiency in final use can vary from almost complete utilization of available energy down to only a very few per cent. The extent of actual energy utilization by specific end-use has so far not been thoroughly

studied but, as an initial step and for purposes of this discussion, it is assumed that on average one-quarter of available heat energy is lost or wasted. The attached diagram thus reflects the assumption that "effective" energy, which in fact meets the energy requirements of the end-user, is consequently only about three-quarters of the heat energy originally available from the combustion of the fossil fuels.

Although kerosene, to quote one example, may be used for either heat or in certain engines for mechanical work, in the absence of the requisite detailed statistics the attached diagram reflects the assumption that all motor gasoline, diesel oil, aviation gasoline and turbo fuel is used for purposes of producing mechanical work rather than heat, while other petroleum products, i.e. exclusive of such items as asphalt, wax, chemical feedstock, etc. are used for producing heat. Losses and waste of energy in all end-uses depend of course again on particular conditions, equipment, efficiencies, etc., and as a first approximation it was assumed that the actual end-user of energy, who requires certain work to be performed, will obtain only about 30 per cent of the originally available energy, i.e. energy input, in the form of "effective" or "useful" energy. This generalized approximation is again reflected in the attached diagram.

In the case of secondary energy, viz. electricity generation, there exist essentially three types of primary energy inputs, i.e.

1. Fossil fuel heat input
2. Nuclear fuel heat input
3. Hydro power

Thermal power generation via steam production (i.e. based on conventional fossil fuels or on nuclear fuels) involves large losses of energy at various stages of the process, e.g. energy use or losses arising from fuel handling and preparation, imperfect combustion, incomplete heat transfer to steam, inclusive of stack gas losses, boiler feedwater injection power, friction, turbine, electrical generation, transformation and transmission losses. Between the heat input to the boiler and the energy output of the generator, turbine loss is, however, the predominant one, largely because a high vacuum must be maintained in the steam condenser by transferring low temperature heat energy to large volumes of cooling water. Efficiencies in thermal generation of electricity vary significantly and in practice anything from 20,000 Btu's to 8,000 Btu's of heat input may be required to obtain an output of one kilowatthour (kwh) of electricity. For purposes of illustration, an average of 10,000 Btu's of heat input has been selected in the attached diagram as being required to obtain an output of one kwh of electricity.

In examining energy demand from the point of view of the "end-user", it is established that one kwh of electricity can be converted directly into heat by means of a resistance heater, which produces 3,412 Btu's of heat for each kwh of electricity input. However, the major use for electricity is not in the production of heat, but as motive power for the performance of mechanical work. For such a purpose, electricity represents a specially upgraded form of energy and the end-user can rely on an exceptionally high efficiency in the utilization of the available electrical energy if he takes the requisite care in use. For the purpose of this analysis, a utilization efficiency of 95 per cent is assumed.

In the case of fossil fuels, as suggested earlier, the greater bulk of products derived from petroleum (e.g. gasoline, diesel fuel, aviation fuel, etc.) is also used for purposes of providing mechanical work rather than heat, e.g. via the internal combustion engine, the jet engine, etc. These mechanisms, however, operate only at efficiencies of about 25 to 35 per cent. The effective net use of energy thus represents approximately one-third only of actual end-use purchases in the case of gasoline, for example. However, since the physical purchase of gasoline entails the acquisition of a specific volume of the fuel, this is usually the point at which "final energy demand" is measured

in statistical returns, and this is the point at which supply and demand assessments are usually made.

In view of the significant differences in the efficiency of fuels and power at the point of sale to the ultimate customer, however, the difficulties entailed in the aggregation of statistics at this point become apparent. To aggregate electricity, a specially upgraded form of energy, with an efficiency of some 95 per cent, at the point of end-use sale with petroleum products, with an efficiency of only 25 per cent, for example, does not really provide a fair picture of either "gross" demand by the end-user for energy (i.e. inclusive of losses arising from less than full utilization of all potential included in energy purchases) or of effective "net" use of energy (viz. actual utilization of energy, exclusive of "losses").

Current practice varies a great deal in regard to the treatment of electricity in total energy supply and demand aggregations. In fact aggregations are often omitted and only separate totals are shown for fossil and nuclear fuels in terms of Btu's and electric power as measured in kwh respectively. A meaningful aggregation of energy could only be effected on the basis of a common efficiency factor, but such calculation would entail a full evaluation of "end-use efficiency" in energy utilization, a task which at this stage appears impracticable

insofar as requisite basic data have to be developed first and appropriate analyses may involve some extensive research. Such work may eventually be undertaken, but meanwhile the problems of aggregations, where necessary, have to be treated in the light of present knowledge and availability of data.

A further complicating factor encountered in any attempt to aggregate energy statistics occurs because in the case of electricity generation from hydro power, no specific energy value in Btu's can really be attributed to "falling water". For illustrative purposes an input of 4,000 Btu's was, however, assumed in the attached diagram for each kwh (i.e. 3,412 Btu's) of hydroelectric output. This hypothetical energy input figure provides a theoretical allowance for such losses as are due to friction, leakage, etc., in the hydroelectric plant, i.e. the somewhat greater energy input per kwh to the hydroelectric plant than its actual kwh electricity output provides allowances for a combined turbine and generator efficiency of some 85 per cent. In the case of electricity generated from hydro power, the <u>output</u> is of course again measured in kwh and is treated no differently from electricity generated from fossil or nuclear fuels.

In certain contexts and for particular purposes, the implications of substituting one type of energy for another at

the resource end may prove of greater importance than a mere measurement of energy derived from fossil, nuclear or hydro sources. For such purposes a fictional, but very useful, concept has been introduced into the analysis so far described. This fictional concept expresses the contribution of hydroelectricity at the resource end at the rate of the fossil or nuclear fuel equivalent that it replaces, i.e. in what is termed "white coal". In the attached diagram the computed hydro power input of 4,000 Btu's per kwh output has thus been supplemented by a theoretical input (i.e. Difference to White Coal, or D.W.C.) of 6,000 Btu's per kwh of electricity output, which makes up for the total of 10,000 Btu's of heat input assumed to be required on average per kwh of electricity output from thermal generation.

The true comparability of the total per capita energy usage by Norway or Canada, for example, on the basis of "energy inputs" with those of most other countries, which extensively utilize thermally generated power, is considerably reduced unless the suggested hypothetical factor is recognized in the calculations.

In the attached diagram concrete, measurable statistics are shown in solid blocks, whereas the "fictitious" data, shown in broken line blocks, are infused into the diagram to provide a basis for certain specialized economic studies and interpretations.

Although the use of "white coal" in the aggregations inflates the apparent total demand for energy, the introduction of this concept provides a more meaningful basis for inter-provincial, international and historical comparisons. For purposes of trend analyses and establishment of market shares by individual fuels, etc. the aggregations based on the "white coal" concept have also been found in some cases to have more interest and value than the more usual approaches to energy aggregations.

At the final demand end of the analysis or for a "per capita" comparison, the effective end-use assessments are considered to be the more meaningful ones, although it is recognized that a great deal of further detailed work may prove necessary to obtain a more precise definition of energy efficiencies in specific end-use applications.

In summing up, therefore, it may be concluded that in aggregating energy statistics at the resource end, the main difficulty occurs on account of the apparent understatement of the value of hydro power to the economy, which has of course a high efficiency in the direct drive of electricity-generating turbines as compared with the use of steam turbines employing fossil or nuclear fuel generated heat as their energy source.

A province or a country endowed with abundant hydro power will apparently require relatively less resources to meet

its energy requirements, simply because its energy resource utilization will be more efficient and its energy "losses", i.e. the energy dissipated in conversion of energy from heat to electrical power in thermal generation of electricity, will not occur.

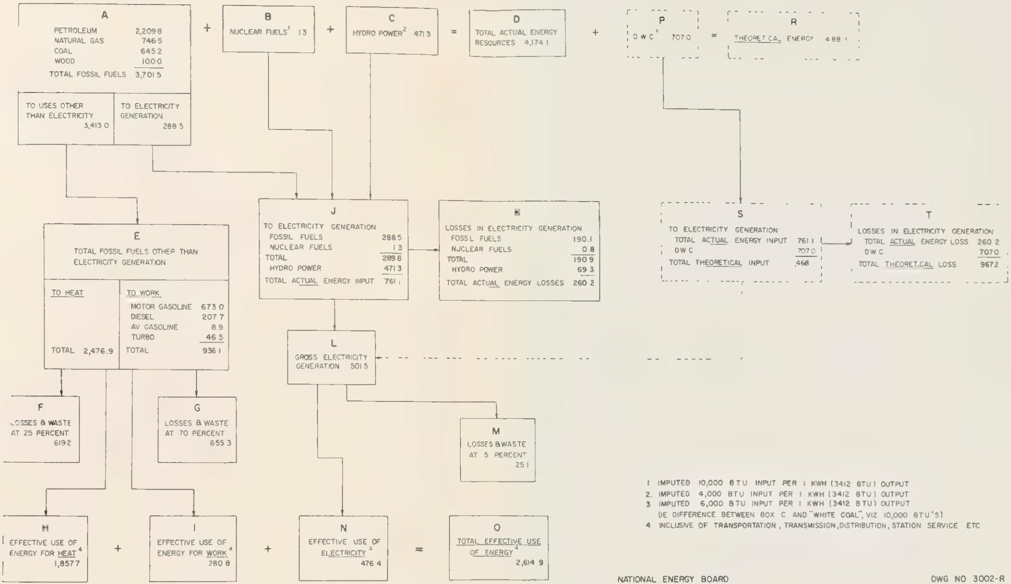
A province or a country using hydroelectricity will consequently exhibit a relatively low "per capita" energy requirement (expressed in Btu's) at the resource end when compared with a province or country relying on thermal electricity generation. Any change in the pattern of electricity generation over a period may result in apparent anomalous energy supply and demand trends.

Taking the data presented in the attached diagram, the following conclusions can be drawn, according to the treatment or interpretation of the statistics:

	Trillions of Btu's
1. Total supply of energy in Canada in 1965:	
a) Actual	4,174.1
b) Computed as if all electricity was generated from fossil or nuclear fuel	4,881.1

TOTAL ENERGY SUPPLY AND DEMAND FOR CANADIAN DOMESTIC MARKET - 1965

10^{12} B.T.U.



1. IMPUTED 10,000 B.T.U. INPUT PER 1 KWH (3412 B.T.U.) OUTPUT
2. IMPUTED 4,000 B.T.U. INPUT PER 1 KWH (3412 B.T.U.) OUTPUT
3. IMPUTED 6,000 B.T.U. INPUT PER 1 KWH (3412 B.T.U.) OUTPUT (I.E. DIFFERENCE BETWEEN BOX C AND "WHITE COAL", VIZ. 10,000 B.T.U.'S)
4. INCLUSIVE OF TRANSPORTATION, TRANSMISSION, DISTRIBUTION, STATION SERVICE ETC.

NATIONAL ENERGY BOARD

DWG. NO. 3002-R